Femtosecond interferometric investigation of initial stages of the shock ignition relevant plasmas generated by laser irradiation of planar targets

T. Pisarczyk¹, S.Yu. Gus'kov², J. Badziak¹, Z. Kalinowska¹, T. Chodukowski¹, P. Parys¹, M. Rosinski¹, A. Zaras-Szydlowska¹, A. Kasperczuk¹, S. Borodziuk¹, N.N. Demchenko², O. Renner³, M. Smid³, J. Hrebicek³, T. Medrik³, D. Batani⁴, L. Antonelli⁴, Y. Maheut⁴, L. Volpe⁴, J. Ullschmied⁵, J. Dostal⁵, R. Dudzak⁵, E. Krousky⁵, M. Pfeifer⁵, J. Skala⁵, P. Pisarczyk⁶

¹ Institute of Plasma Physics and Laser Microfusion, Warsaw, Poland
² P.N. Lebedev Physical Institute of RAS, Moscow, Russian Federation
³ Institute of Physics ASCR, Prague, Czech Republic
⁴ Université Bordeaux, CNRS, CEA, CELIA, Talence, France
⁵ Institute of Plasma Physics ASCR, Prague, Czech Republic
⁶ Warsaw University of Technology, ICS, Warsaw, Poland

Two channel polaro-interferometric system irradiated by the femtosecond laser with the pulse duration of ~ 40 fs was implemented as a main optical diagnostic to investigate the laser-produced plasma on PALS (Prague Asterix Laser System). The application of such short pulse diagnostic allowed us to probe the ablative plasma created during interaction of the laser radiation with a target, which was not feasible in the hitherto interferometric measurements. The experiments were performed using planar targets consisting of a massive Cu plate over-coated with a thin CH layer, which was irradiated by the 1ω PALS laser beam (λ=1.315 μm) at the energy of 250 J. The intensity of the fixed-energy laser beam was scaled by varying the focal spot radius. To imitate the shock ignition (SI) conditions, the lower-intensity auxiliary 1ω beam created CH-pre-plasma, which was irradiated by the main beam with a delay of 1.2 ns, thus generating the shock wave in the massive part of the target.

The main objective of this research was determination of the electron density distribution of the ablative plasma created during the interaction of the laser pulse with the target, and correlation of this distribution with results of electron temperature measurements and parameters of fast electron and ion emission. Therefore, interferometric studies were carried out along with: (i) spectroscopic measurements in the X-ray range, (ii) measurements of the ion emission by means of ion collectors and (iii) measurements of the volume of craters produced in massive targets providing information on efficiency of the laser energy transfer to the shock wave. 2D numerical simulations exploiting the ATLANT-HE code and an analytical model that includes fast electron generation and transport have been used to support the interpretation of experimental data.

The results obtained by interferometry as well as by other diagnostics prove that the fraction of the main laser beam energy deposited into the bulk copper decreases in comparison with the case of the target irradiation at absence of the pre-plasma. In the case without pre-plasma, resonant absorption is expected to play a significant role. So, we suppose that the presence of pre-plasma decreases the resonant absorption and, as a consequence, decreases the positive contribution of fast electrons to laser energy deposition in the bulk copper. This is confirmed by numerical modeling although no direct measurements of hot electrons have yet been made.